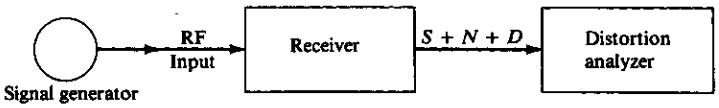


**FIGURE 3.24**
SINAD-measuring network.

## ■ 3.6
## PROBLEMS

**3.1** Determine an expression for the total noise voltage squared across the output terminals of the circuit shown in Fig. P3.1.

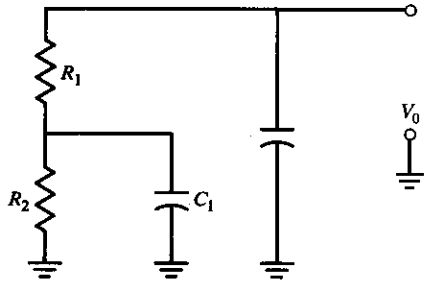


**FIGURE P3.1**
Frequency-dependent network including two noise sources.

**3.2** Calculate the 3-dB and noise bandwidths of the circuit shown in Fig. P3.2.

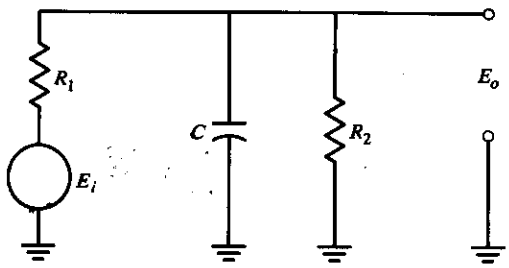


**FIGURE P3.2**
Frequency-dependent network with two noisy resistors.

**3.3** Show that the amount of excess noise $E_n^2 = (k/f)\,df$ generated in each decade of frequency is constant, independent of frequency.

**3.4** Derive the equation for the noise factor of $n$ cascaded networks, each with a noise factor $F_i$ and power gain $G_i$.

**3.5** Determine the equivalent input noise sources of a common-base amplifier in terms of the thermal and shot noise sources.

**3.6** A receiver has a 3-kHz bandwidth, a 50-$\Omega$ input impedance, and a 5-dB noise figure. It is connected to an antenna by means of a 50-$\Omega$ coaxial cable that has an equivalent gain (loss) of $-3$ dB. What is the overall noise figure?

**3.7** A receiver with an 8-dB noise figure, a 50-$\Omega$ input impedance, and a 3-kHz bandwidth is connected to an antenna that has a noise temperature of 2000 K. What is the minimum detectable signal for a 10-dB output signal-to-noise ratio? If a preamplifier with a gain of 10 dB, an NF of 5 dB, and bandwidth of 4 kHz (which overlaps the receiver's frequency response) is added between the antenna and receiver, what is the minimum detectable signal for a 10-dB output signal-to-noise ratio?

**3.8** A receiver is to be designed to have an overall noise figure of 4 dB. The input mixer has a noise figure of 8 dB, and the preamplifier (which is to be located at the input) has a noise figure of 3 dB. What must be the minimum preamplifier gain?

**3.9** An amplifier with a 10-dB noise figure and a 4-dB power gain is cascaded with a second amplifier which has 10-dB noise figure and a 10-dB power gain. What are the overall noise figure and power gain?

**3.10** Calculate the value of source resistance which will minimize the noise figure of a 741 operational amplifier at a frequency of 500 Hz. What is the minimum noise figure?

**3.11** A 741 operational amplifier is used with a source resistance of 20 k$\Omega$. If the input signal level is 1 mV, what is the output signal-to-noise ratio? Assume that the amplifier bandwidth is 1 Hz and that the center frequency is 1 kHz. What is the output signal-to-noise ratio with the source resistance that minimizes the noise figure?

**3.12** Consider an amplifier in which the source resistance is larger than that required to minimize the noise figure. Show that shunting the source with a resistor in order to minimize the noise figure will reduce the output signal-to-noise ratio.

**3.13** A receiver with a 3-kHz bandwidth and 50-$\Omega$ input impedance has a noise figure (NF) of 8 dB. What is the minimum detectable signal for an output signal-to-noise ratio of 10 dB? If the two-tone intercept point is $+20$ dBm, what is the receiver's dynamic range? What will be the dynamic range if a linear noiseless preamplifier with a voltage gain of 10 is added at the input?

**3.14** A receiver has a 10-dB noise figure, a 50-$\Omega$ input impedance, a $-5$-dBm two-tone intercept point ($P_I$), and 3.5-kHz bandwidth. What is the minimum detectable signal for a 0-dB output signal-to-noise ratio? What is the receiver's dynamic range?

**3.15** A linear preamplifier with a voltage gain of 5 and a 4-dB noise figure is inserted before the receiver of Prob. 3.14. What is the overall dynamic range?

**3.16** A receiver has a 3-kHz bandwidth, a 70-Ω input impedance, and a noise figure of 6 dB. It is connected to an antenna with a cable which has an equivalent loss of 6 dB and an NF of 3 dB. (The cable is matched to the input impedance.) What is the minimum detectable input signal for an output signal-to-noise ratio of 10 dB? If the antenna noise temperature is 3000 K, what is the minimum detectable signal for the same output $S/N$?

**3.17** Use a transistor with $\beta = 100$ to design a common-emitter amplifier to couple a 100-Ω source to a 1-kΩ load resistance. The base spreading resistance can be neglected. What is the optimum value of collector current for the lowest noise figure?

**3.18** A network consists of a voltage source with a 1-kΩ source resistance and a 1-kΩ load resistance. Determine the noise factor at 100 Hz and at 10 MHz. Also determine the total output noise power.

**3.19** Describe the noise characteristics of the amplifier you designed for the Chapter 2 Spice project. Determine the noise factor at 100 Hz and at 10 MHz. Also determine the total output noise power. The measurements should be made with the source matched to the amplifier input impedance. Can you determine the equivalent input noise generators? (*Note:* Add KF = 1E-13 to the transistor model. This is a flicker noise coefficient.)

## ■ 3.7

### REFERENCES

1. Y. Netzer, The Design of Low-Noise Amplifiers, *Proc. IEEE,* **69:** 728–741 (1981).
2. IRE Standards on Methods of Measuring Noise in Linear Twoports, *Proc. IRE,* **48:** 60–68 (1960).

## ■ 3.8

### ADDITIONAL READING

Carson, R. S.: *Radio Communications Concepts: Analog,* Wiley, New York, 1990.

Das, M. B.: FET Noise Sources and Their Effects on Amplifier Performance at Low Frequencies, *IEEE Trans. Electron Devices,* ED-19, 1972.

Fisk, J. R.: Receiver Noise Figure, Sensitivity and Dynamic Range—What the Numbers Mean, *Ham Radio,* October 1975, pp. 8–25.

Fris, H. T.: Noise Figures of Radio Receivers, *Proc. IRE,* **32:** 410–422 (1944).

Goldman, S.: *Frequency Analysis, Modulation and Noise,* McGraw-Hill, New York, 1948.

Motchenbacher, C. D., and F. C. Fitchen: *Low-Noise Electronic Design,* Wiley, New York, 1973.